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14. ABSTRACT
The project goal, to demonstrate electrical detection of electron spin transport in a semiconductor, has been met. We have achieved a clear spin-valve effect in an in-plane magnetic field and coherent precession and Hanle effect in a perpendicular magnetic field using a silicon spin transport device.

15. SUBJECT TERMS
hot electrons, semiconductor, electron spin

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Final Report

N00014–06–1–0039 Ian Appelbaum , University of Delaware, 1/1/06-12/31/06

The goal of this project was to demonstrate a method to electrically detect electron spin in the conduction band of an arbitrary semiconductor. The proposed method utilizes ballistic spin filtering of hot electrons through a ferromagnetic thin film for polarization analysis. Group III-V semiconductors were first chosen because there exist prior work confirming spin generation and transport in these materials with optical methods, and this was suggested as a way to eliminate unknowns in material parameters with semiconductors outside the range of applicability of the former state-of-the-art. However, partially due to the long lead time for GaAs epitaxial wafers, we fabricated the required semiconductor-metal-semiconductor devices from Silicon (Si), and used electrical methods for both spin injection and detection.

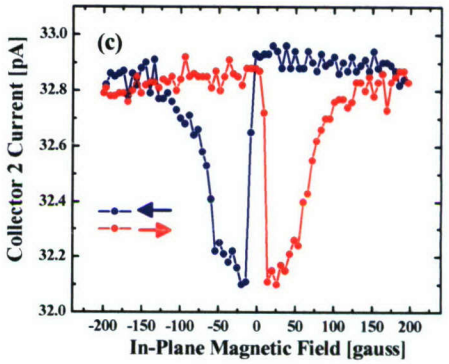

Figure 1: Spin-valve effect at 85K in our 4-terminal spin injection-detection device.

Hysteresis measurements at low temperature (85K) with an in-plane magnetic field showing a clear spin-valve signal confirmed the coherent transport of electron spin through 10 microns of "float-zone" Si (see Figure 1). We also observed coherent spin precession in a perpendicular field (Figure 2). Our device design allows essentially independent control over the drift field and current, causing the shift of precession peaks from (a) to (c) in Fig. 2 which is the result of shortening the transit time from injection to detection with an accelerating field. We analyzed the transit-time dependence of the magnetocurrent signal to put a lower bound on the spin lifetime of several ns.

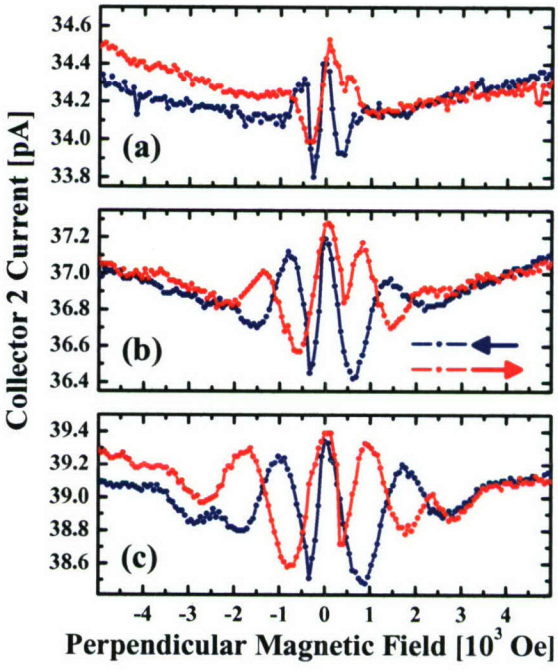

Figure 2: Spin precession in a perpendicular magnetic field and different collinear accelerating electric fields from applied voltage bias of 0V (a), -0.5V (b), and -1.0V (c).

Papers acknowledging ONR support:

Ian Appelbaum, Biqin Huang, and Douwe Monsma, "Electrical measurement and control of spin transport in Silicon", submitted to Nature, Dec 22 2006.

Biqin Huang, Igor Altfeder, and Ian Appelbaum, "Spin-Valve Photo-Transistor", Appl. Phys. Lett. **90**, 052503 (2007) *featured on the Jan. 29 2007 cover.*

Igor Altfeder, Biqin Huang, Ian Appelbaum, and B.C. Walker, "Self-assembly of Epitaxial Monolayers for Vacuum Wafer Bonding", Appl. Phys. Lett. **89**, 223127 (2006)

Biqin Huang and Ian Appelbaum, "Perpendicular Hot-Electron Transport in the Spin-Valve Photodiode", J. Appl. Phys. **100**, 034501 (2006)

Patent Applications resulting from ONR support:

Ian Appelbaum and Igor Altfeder, "Electrically Anisotropic Films for Heterogeneous Semiconductor Integration", provisional application submitted

Ian Appelbaum, "Method and device for electrical measurement and control of spin transport in semiconductors" (in preparation)